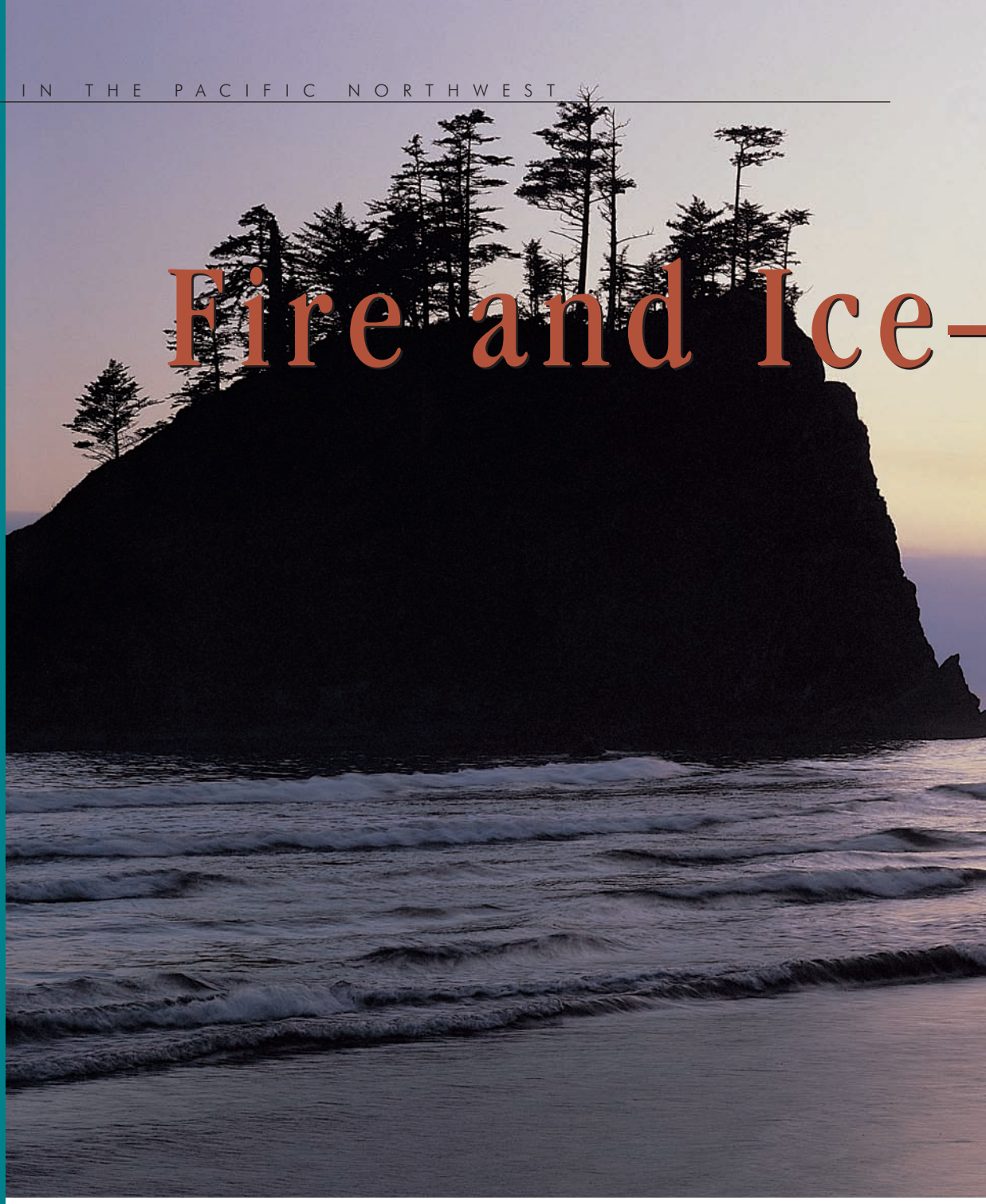
Fire and Ice–



PEOPLE TO KNOW

J. Harlen Bretz

PLACES TO LOCATE

Asia
North America
Pacific Northwest
Columbia Plateau
Palouse Hills
Cascades
Olympic Mountains
Okanogan Mountains
San Juan Islands
Mt. St. Helens
Mt. Rainier
Grand Coulee
Dry Falls
Puget Sound
Columbia River
Toutle River

WORDS TO UNDERSTAND

abrasive
aquifer
basalt
cataracts
continental drift
coulee
decompose
deluge
dormant
erratics
fault lines
fissure
geologic time
geologist
igneous rock
lahars
loess
molten
sedimentary
tectonics

A Timeline of Washington's Geologic History

*MYA means millions of years ago

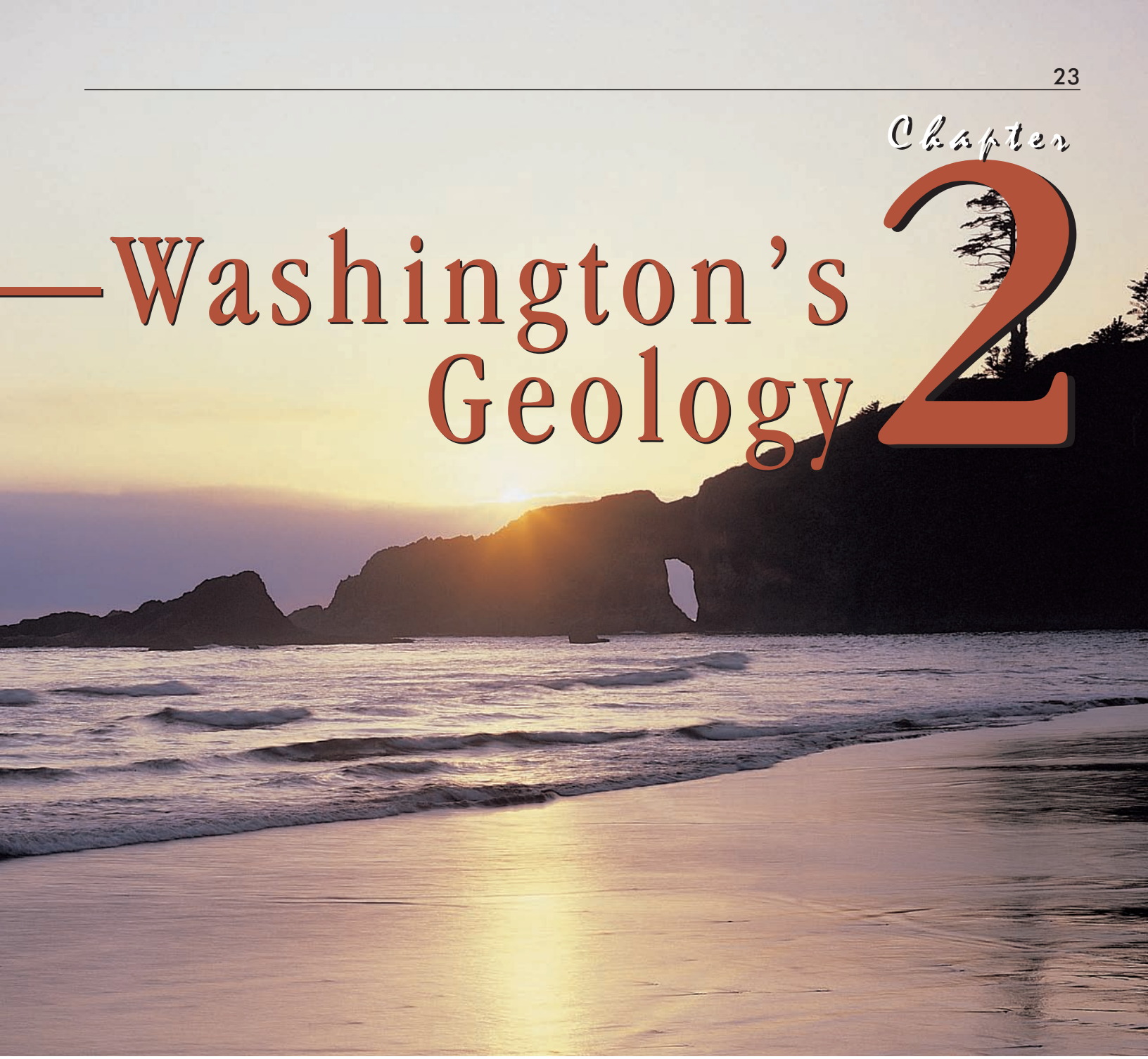
TIMELINE **600** mya* **500** mya **400** mya

Precambrian Era
(85% of the earth's time period)

Paleozoic Era (570–240) MYA
Pangaea supercontinent divides.
Shallow seas cover most of North America.
Trilobites, amphibians, and reptiles live in the seas.
Coal is formed.

Chapter 2

Washington's Geology



Geologic forces drastically changed our coastline. Millions of years ago, the coast was in the Spokane region. Second Beach in Olympic National Park is elegant at sunset. *Photo by Tom Till*

300 mya | **200** mya | **100** mya | **PRESENT**

Mesozoic Era (240–65) MYA
Sedimentary rock is formed.
Rocky Mountains begin to take shape.
Okanogan micro-continent joins North America.

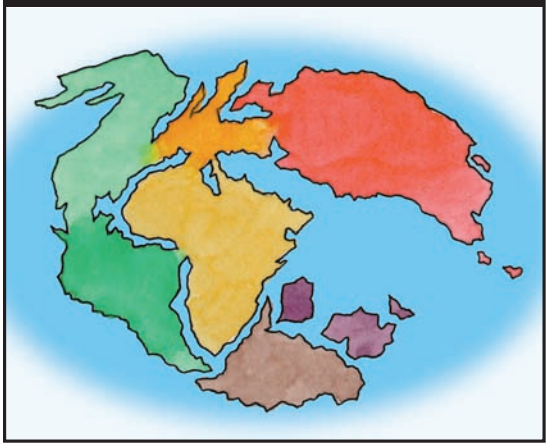
Cenozoic Era (65 MYA to present)
North Cascades micro-continent docks against the mainland.
Volcanic activity forms the Cascade Range.
Lava flow forms the Columbian Plateau.
Ice Age glaciers blanket northern Washington.
Glaciers carve valleys. Melting ice forms lakes.
Pacific Coast changes as ice melts.
Grand Coulee and Dry Falls were eroded by floods.
Olympic Mountains are formed.
Humans hunt mammoths in the Pacific Northwest.

A Changing Land

Millions of years before human life began, powerful geologic forces started shaping the Pacific Northwest.

Continental drift is a term used to describe movement of the largest land masses. About 200 million years ago, scientists think that Africa, Europe, Asia, the Americas, and Australia were joined together in a huge supercontinent called Pangaea. Then the continents drifted apart, creating a narrow Atlantic Ocean. The Atlantic Ocean widened, causing North America to move west. The Atlantic has continued to widen one to three inches a year.

ANCIENT PANGAEA



A Jigsaw Puzzle

The shape of North America also changed. Eastern Washington used to be part of the coast of the North American continent. Spokane would have been on that seashore long ago. The rest of our land was still underwater.

A Micro-continent is a very small continent.

Land areas along the old coast changed as a result of a collision between the continent and the floor of the Pacific Ocean. A piece of the old coastal plain was crushed into a long belt of folded ***sedimentary*** rock. A portion of this belt extending from Washington into British Columbia is called the Kootenay Arc.

The next pieces of the puzzle to be added were the Okanogan and North Cascades micro-continents.

Tectonic forces caused the micro-continents to "dock" against the main continent. Many of the fossil remains found in the North Cascades resemble those of a similar age found in Southeast Asia. The North Cascades' granite rock is different than the volcanic rock of the rest of the Cascade Range. This leads geologists to believe that the landmass was once a separate continent joined to Asia.

Massive Floods

Starting about 15,000 years ago, a series of enormous floods swept across what is now eastern Washington and down the Columbia River. These floods came every fifty to sixty years for over 2,000 years. A great ***deluge*** swelled the Columbia River until it contained ten times the flow of all the rivers in the world today! The water eroded the landcape over and over.

What could have been the source of all that water? How did it affect our current landscape? What geologic changes are still occurring today?

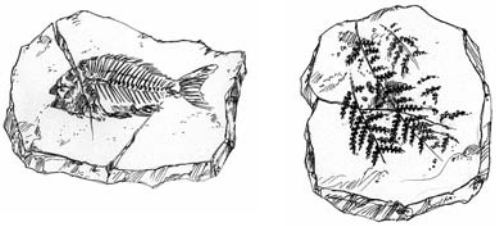
Fossils Are Clues to the Past

Fossils tell us what kinds of animals and plants once lived in a region. Sometimes the imprints are found in rocks. Sometimes thousands of shells are found in layers of rock. Sometimes entire skeletons of ancient animals and people are unearthed.

Shells and bones from ancient sea life tell us that oceans once covered our land. Fossils of ferns and other plants in central Washington indicate that a large tropical rainforest once flourished there.

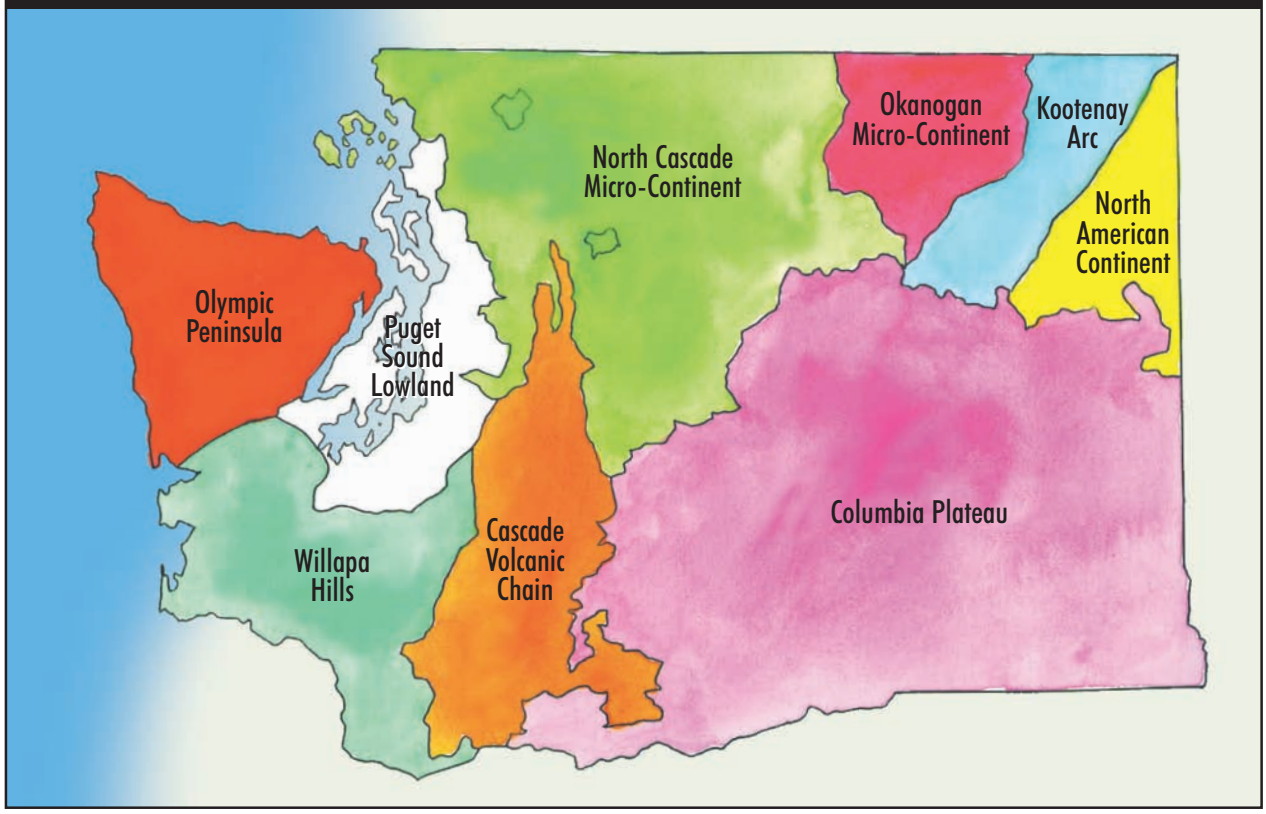
Fossil Fuels

Coal was formed by the combination of prehistoric plants, heat, and pressure over millions of years. In the wet climate of prehistoric times, ferns and other plants lived and died. Just like today, they ***decomposed,*** layer upon layer. In



Geologists *study rocks, land formations, and fossils to learn the history of the land.*

GEOLOGIC JIGSAW



time, rock and earth covered the plants. Later, when mountains were thrust upward, the rock sometimes contained layers of coal. Other deposits were still under the ground.

Today, coal is burned to provide the heat that boils the water that makes the steam that runs the generators that produce electricity. There are fairly large coal deposits in King, Kittitas, and Lewis counties.

Plate Tectonics

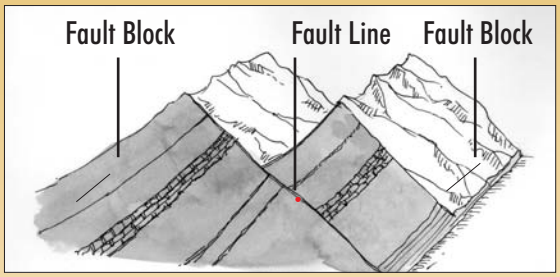
Tectonic forces are strong forces in the earth that cause landmasses to move. They also cause the earth to fold and crack.

The earth's crust may be made up of around twenty moving plates. These plates carry both the earth's continents and pieces of the ocean floor. In some places plates spread apart, and in other places they collided with, or scraped against, each other.

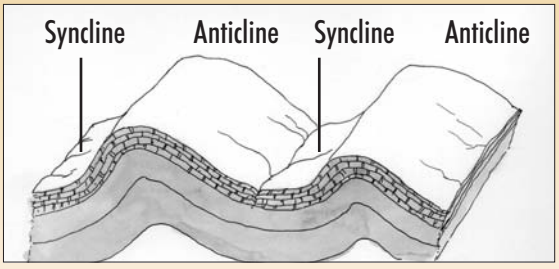
Earthquake!

Tectonic forces left ***fault lines***—fractures in the earth's crust—in the Puget Sound region and off the Pacific Coast. A shift in one of the landmasses causes earthquakes every few years.

About a thousand years ago, there was a major earthquake where Seattle is now. More recent large shakes occurred in 1949, 1965, and 2001. The potential for a "big one" is always there.



Fault-Block Mountains



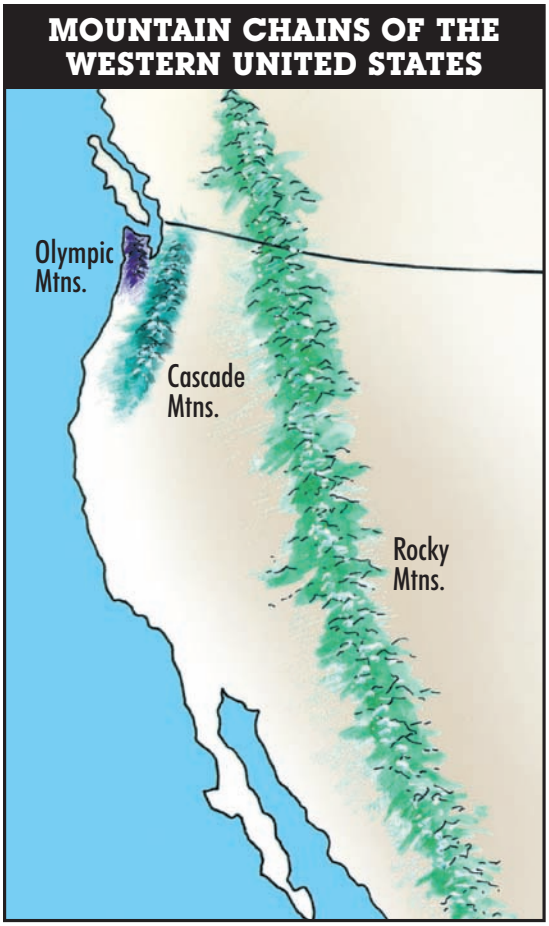
Folded Mountains

Forming Our Mountains

Mountain ranges were uplifted, tilted, and folded in various ways. You can see the folded and tilted layers of rock as you explore mountain canyons. The uplifting is partly the result of the tectonic forces that pushed huge ridges of land against each other. Where the two landmasses met, land ridges were forced upward.

After the mountains were formed, erosion by moving wind, water, and ice started immediately. That is why older mountains are more rounded, and younger mountains are more jagged.

The Rocky Mountains are the oldest mountains in the West. Both the Cascades and the Olympic Mountains are much younger. Because so much of our land was still underwater when the mountains were forming, the Olympic Mountains, the youngest in the state, were once off-shore islands.



The sun rises over the Olympic Range near Mt. Olympus, as it has for millions of years. The Olympic Mountains are some of the newest in the world. *Photo by Tom Till*

Mt. Angelos in the Olympics shows the dramatic upthrusting of what were once horizontal sedimentary rock layers. Now they stand on end!
Photo by Eugene Kiver

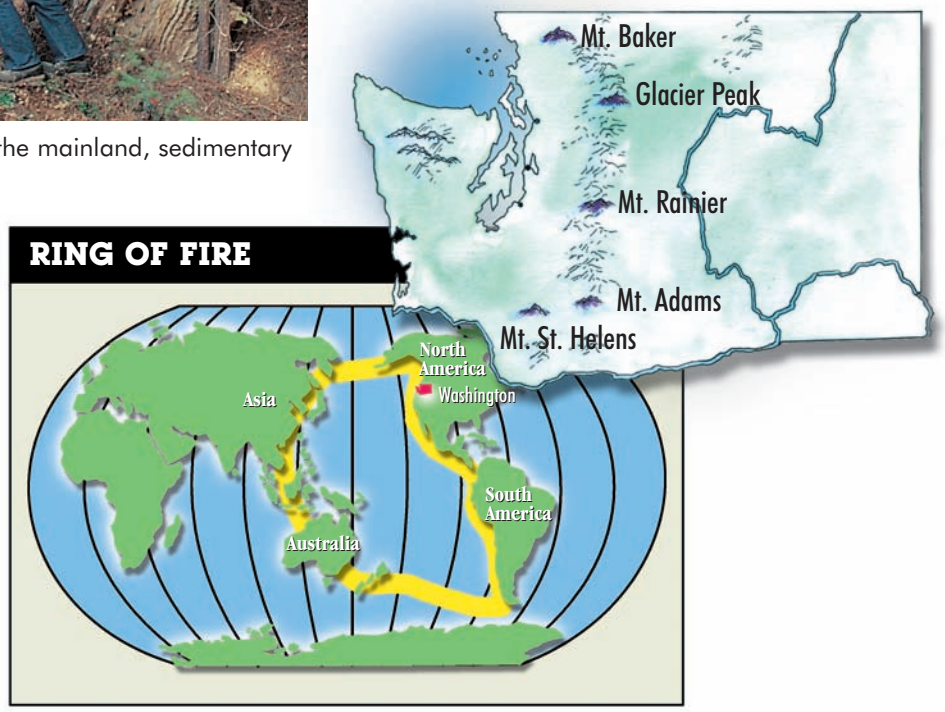
When the Okanogan micro-continent slid into the mainland, sedimentary rock layers tilted upward. *Photo by Eugene Kiver*

Mountains of Fire

Mountains were also formed by volcanic action. After the upthrusting, folding, and faulting, volcanic activity occurred in both the Cascade and Olympic Mountains. They are part of a great Ring of Fire that includes volcanoes in Indonesia, the Philippines, Japan, Alaska, and the west coast of North and South America. How were these tall mountains formed?

Steam and gases expanded inside the earth until the pressure was too great for the earth to withstand. Then ***molten*** (liquid) rock called lava rose to the surface of the earth's crust in a violent explosion. The lava flowed down the mountainside, building it higher and higher.

The Cascades include Washington's five "sleeping giants." Mt. Baker, Glacier Peak, Mt. Rainier, Mt. Adams, and Mt. St. Helens are ***dormant*** now. That means they are not active. No one knows when they will "wake up" and again cover the land around them with lava, mud, and ash.



If you live in a region that might be affected by volcanic eruption, floods, earthquakes, or other geologic activity, call your state emergency preparedness office to see if there are plans to deal with a catastrophe. Is your family prepared for an emergency?

THE LESSONS OF MT. ST. HELENS

It was May 18, 1980. Mt. St. Helens awoke with an eruption equal to 21,000 atomic bombs the size of those dropped on Japan at the end of World War II. This mountain was the youngest of the Cascade volcanoes and had been fairly active over the past 300 years. It was so active, in fact, that Indians had been afraid of the mountain and seldom traveled on the highest places.

Mt. St. Helens loomed tall before the eruption. *Photo by Karen Jacobsen*

No lava flowed from the mountain during the eruption.

A few months earlier, in late March, tremors deep in the mountain signaled that an eruption was likely. By early May, a large bulge began to form on the mountain's north side. A week later, a large patch of the mountain turned into a churning brown liquid mass and began to slide downward. Then came an enormous explosion and a chain reaction of catastrophic events.

The collapsing mountain filled the north fork of the Toutle River with debris 600 feet deep. ***Lahars***, huge mud flows containing boulders and uprooted trees, filled the river all the way to its junction with the Cowlitz River. That river carried the load down to the Columbia River, where the mud clogged up the river, closing it to ocean-going vessels.

A towering cloud of ash and gas from the erupting volcano rose 12 miles into the air, where winds carried it across the continent. Ash choked automobile air filters, causing vehicles to stall. In Spokane, 200 miles to the east, visibility was reduced to 10 feet and the airport was forced to close.

In the immediate blast area, ice and snow were melted quickly. Tens of thousands of stately Douglas firs 6 feet in diameter and 200 feet tall were laid flat over an area of 250 square miles. The earth beneath them was blown away to bedrock. All the wild land animals, fish, and birds were killed.

The damage from the eruption was caused by gas, ash, and flowing mud. *Photo by Don Wilson*

The top of Mt. St. Helens was blown away, leaving only a huge rock crater. Spirit Lake is now filled with debris.
Photo by Lori Smith

Deadly Consequences

Fifty-seven people lost their lives in the eruption. Probably the first to die was David Johnston, a geologist who had permission to set up his monitoring equipment six miles north of the mountain. Johnston and his colleagues had greatly underestimated the wide range and force of the eruption. He had time for one brief radio message. "Vancouver, Vancouver, this is it!" were his last words. His jeep, trailer, and his body were never found.

Why did people risk their lives by staying so close to the mountain? The story of eighty-four-year-old Harry R. Truman provides one explanation. Truman had operated a resort on Spirit Lake since 1926. When he was urged to leave, Truman stubbornly refused. He had a lot of money invested in his lodge. He had sixteen cats that depended on him. This was his home, filled with memories of his wife who had died. As he put it, "If the mountain did do something, I'd rather go right here with it." Truman was buried under several hundred feet of volcanic debris.

The Mountain Today

Nature destroys, but it also heals. Plants and animals are slowly reclaiming the scarred landscape, and the mountain has become a place to study volcanoes, earthquakes, and changes to the environment.

Visitors to the three Mt. St. Helens National Monument visitor centers typically ask two questions. The first: "Will the mountain explode again?" The answer is "Yes." The second: "When?" The answer is "We do not know."

In ***geologic time***, the eruption was an ordinary event, typical of the forces that have always shaped our physical environment. It serves as a powerful reminder that geologic forces continue to work.

Our Most Dangerous Volcano

Geologists today are concerned about Mt. Rainier, Washington's largest dormant volcano. Mt. Rainier, a towering pile of loose rocks and a cubic mile of glacier ice, looms over the Puget Sound region near Seattle and Tacoma.

Rainier's capacity for destruction is truly frightening. Geologists consider the mountain to be dangerously unstable. If Rainier collapses in an earthquake or the volcano erupts, an avalanche of red-hot lava and ash will sweep down the mountain. Huge lahars of mud and ice will travel swiftly down river valleys. Thousands of people will have less than an hour to flee the destruction. Geologists predict a one-in-seven chance of that happening in the lifetime of anyone living in the potential path of destruction.

One comes more intimately in touch with the mountains when he travels the trails. . . . Here where vegetation makes its last stand amid a world of ice and snow, with the lower world stretching away to the horizon, nature unfolds in all her beauty.

—Asahel Curtis, naturalist

Mt. Rainier's enormous ice cap looms beautiful and threatening. *Photo by Asahel Curtis*

Forming the Columbia Plateau

Volcanic activity formed more than mountains. Lava also helped form the relatively flat Columbia Plateau. It is one of the largest and most spectacular volcanic regions in the world. Repeated eruptions from long ***fissures*** (cracks in the earth's crust) covered the plateau with lava that sometimes spread out more than 100 miles from its source.

Rich Soil of the Palouse

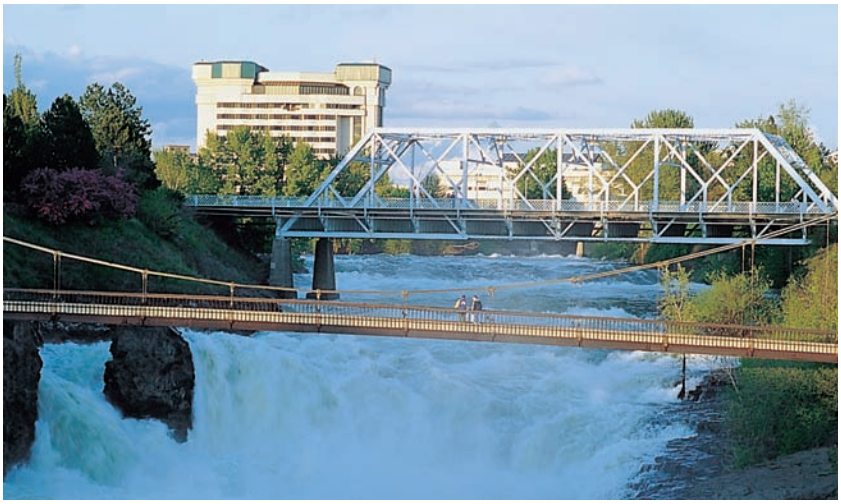
After the lava flows ended, another feature changed the landscape. Rich soil was formed by deposits of glacial ***loess***. Loess is a mixture of fine volcanic ash and dust carried by wind before being deposited on the ground in another place. Soil up to 150 feet deep gradually covered large regions of rock. Today, this is the Palouse wheat-growing region in eastern Washington.

Basalt

Basalt is ***igneous rock***, formed of hardened lava. Overlapping basalt layers of the plateau are up to over 4,000 feet deep, leaving geologists to speculate about what might be buried beneath them.

Basalt takes many forms when it cools. This form, in columns, was more easily eroded. *Photo by Mike Green*

Loess soil on Steptoe Butte forms the rich farmland of the Palouse Hills region. *Photo by Bill McKinney*



The falls on the river in downtown Spokane are the result of a smaller basalt flow that originated on the city's South Hill and moved down across the river. *Photo by Barbara Murray*

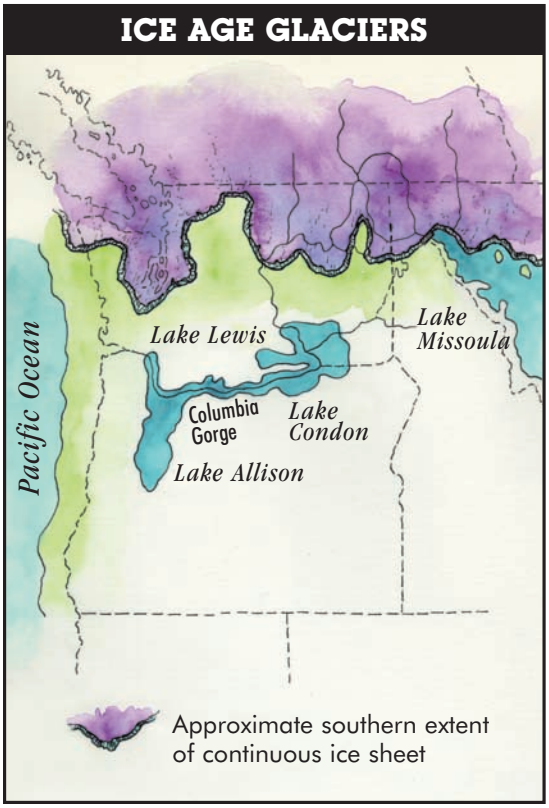
Ice Age Washington

A long time after the major lava flows ceased, the air got much colder. Snow fell much of the year. Snow and ice accumulated, and the polar ice cap moved southward. The continental ice sheet moved into what is now Canada and the northern areas of what is now the United States. The cooling and warming happened over and over again. We call the last glacial period the Ice Age. It happened about one million to ten thousand years ago.

A mile is 5,280 feet. Glaciers were over a mile thick in some places.

Huge boulders that were carried long distances by glaciers or glacial melt flood water are called ***erratics***. This one is located a few miles southwest of the Tri-Cities and probably came from northern Idaho.

Photo by Gary Kleinknecht



The moving glaciers shaped the Puget Sound lowlands, filling in some areas of the landscape and carving out others. The ice sheet was 5,000 feet thick over the place where the city of Bellingham is today. It was 4,000 feet thick over the place where Seattle is today, and 1,800 feet over the Tacoma region. The Ice Age glaciers ended south of present-day Olympia.

The Great Floods

Glacial action also produced the great floods described at the start of this chapter. The ice sheet blocked the Clark Fork River near the present Idaho-Montana border, forming an ice dam half a mile high. The water backed up and formed a prehistoric lake. Lake Missoula was larger than any lake in the western United States today. It was about half as large as Lake Michigan. When the rising water from glacial melt became deep enough, the force of the water tore over and through the ice dam, unleashing an immense flood. Ice, debris, and water rushed out at speeds of up to fifty miles per hour.

The progression of the glacier then created a new dam and formed a new lake that produced yet another flood. This process was repeated every 50 years or so for 2,000 years. The site of today's city of Spokane was repeatedly covered by water over 500 feet deep. Today, Spokane draws its water from a huge ***aquifer*** created by the great floods.

Filled with rocks and chunks of ice as ***abrasive*** agents, the floods spread out across the Columbia Plateau, leaving a sculptured landscape where there had been a mostly level landscape before the floods.

Grand Coulee

Large sections of eastern Washington were sculpted by ice and flood water. The ice plugged the Columbia River and forced the water out of its regular channel. Water flowed across the Columbia Plateau, eroding the rock of the Grand Coulee. A ***coulee*** is a dry streambed.

Today, the Grand Coulee is one of the state's most spectacular geologic features. It is between one and six miles wide and fifty miles long. Halfway down the channel is Dry Falls, site of the largest prehistoric waterfall the world has ever known. During Ice Age melting, water spread out over three miles, thundering over the 400-foot-high falls.

Geologists now think that at the very peak of the huge floods, Dry Falls and the five smaller ***cataracts*** (large waterfalls) to the east were actually submerged for a time. As the glaciers melted and the ice dams broke up, the waters retreated, leaving the coulee region high and dry. This process was repeated many times.

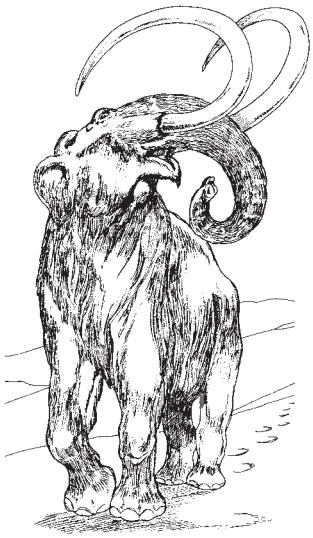
Millions of years ago, the falls were the largest in the world. Tons of water cascaded over the basalt cliffs. Dry Falls, like its name implies, has no water flowing over its basalt cliffs anymore.
Photo by Dale Stradling

J. HARLEN BRETZ

The story of the great floods is a geological detective story. America's leading geologists could not agree that the floods existed. There was one geologist, however, who spent most of his life trying to convince his colleagues that the floods had actually happened. From the early 1920s through the 1960s, J. Harlen Bretz argued the case of the Spokane Flood. His peers scoffed at his ideas, but he persevered. How else, he said, could you explain the breadth and depth of the water-scoured coulees, the enormous gravel bars topped with giant ripple marks, and the huge abandoned cataracts and dry water falls?

Slowly, the Bretz theory came to be accepted by his fellow geologists. By then, Bretz was nearly ninety years old. Satellite photographs now show the full extent of the flood-ravaged land that Bretz laboriously explored on foot. Today, in recognition of his accomplishment, most geologists call the great floods the Bretz Floods.

With a touch of humor, Bretz captioned the above photo of himself: "Five great men in one picture—four of them didn't show."



Ice Age Animals

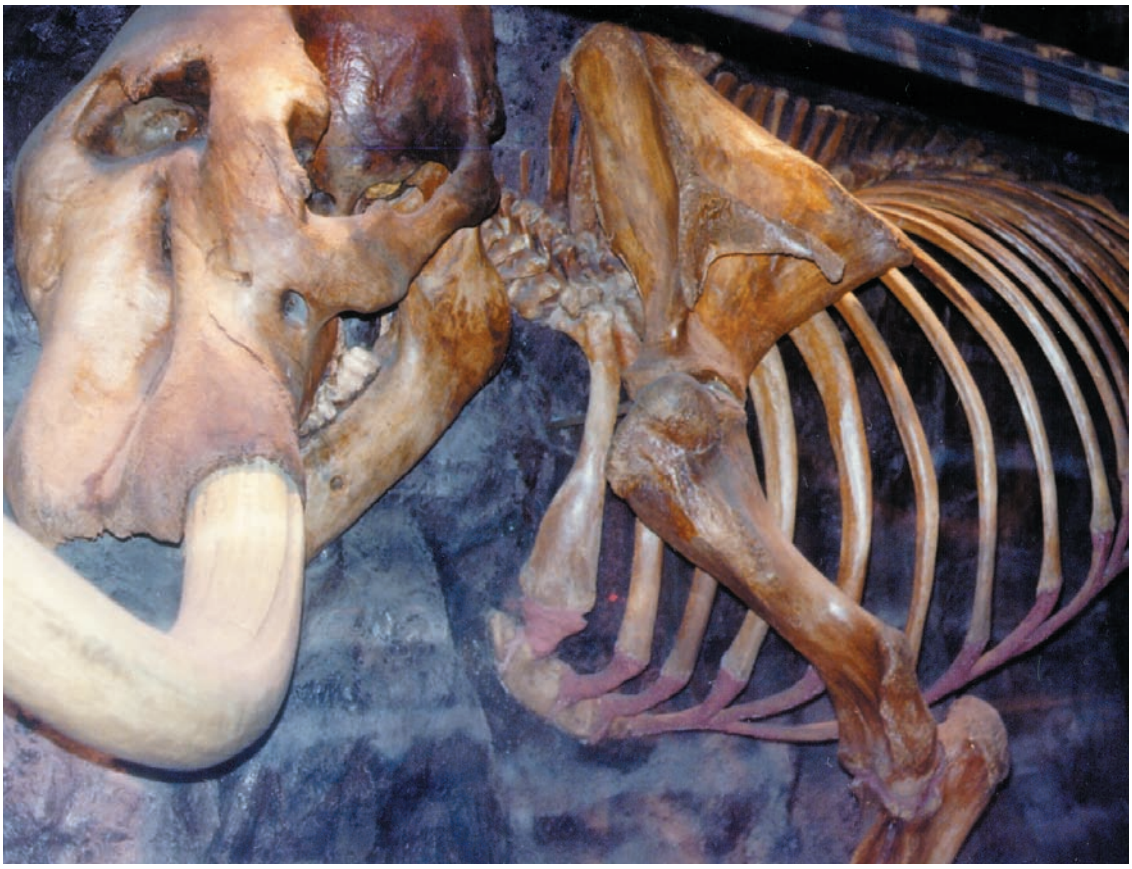
Washington's most spectacular prehistoric animal remains are those of the Columbian Mammoth. The large animals had long shaggy hair and long curved tusks. They lived in many places in North America during and after the Ice Age.

Skeletal remains of at least six mammoths were taken from a swamp in Spokane County in the 1870s. In 1886, bones from several of the mammoths were combined into one giant skeleton. In 1893, the mammoth skeleton was exhibited at the Chicago World's Fair. Since 1914, the mammoth has been on display at the Field Museum in Chicago.

Buried Bones

Dinosaurs lived before the Ice Age. Their bones have been found in many places of North America, but they are curiously missing in the Washington region. Geologists think that dinosaurs might have lived on the Columbia Plateau, but that very thick layers of igneous rock buried their remains.

In 1998, Mrs. Sara Aebly's second grade class at Windsor Elementary School near Spokane got the state legislature to make the Columbian Mammoth the state's official fossil.



Long after the dinosaurs became extinct, giant mammoths, sloths, saber tooth tigers, camels, and giant bison lived in many regions of North America and in the Pacific Northwest.

Glaciers and the First People

Glaciers shaped the physical environment of Washington in spectacular fashion. During the Ice Age, so much water was frozen into ice that the level of the ocean went down hundreds of feet. In Europe, Britain and France were connected by land. The land along our Pacific Coast extended at least 25 miles, and in places more than 100 miles, farther out to sea than it does today.

Many scholars believe the Ice Age glaciers made it possible for groups of people to make their way out of Asia into the Americas. So much of the ocean water was frozen that a land bridge up to a thousand miles wide was exposed, linking Alaska and Siberia. We will discuss this more in Chapter Three.

ACTIVITY

Oral History Interview

You can learn a lot by talking to a person who has witnessed an important event. The eruption of Mount St. Helens was one of these events. There may be other important events relating to natural disasters or changes in the environment where you live.

Conduct an oral history interview with these guidelines:

1. Select a person to talk to and then make an appointment for the interview.
2. Research your project. Go to the library and use the Internet to read magazines or newspaper articles, or even books, on your subject. You might research a volcanic eruption, a flood, a mudslide, a drought, or other event.
3. As you research, develop a questionnaire. This will be an outline of topics you wish to cover during your interview. Use words such as "explain, discuss, describe." Avoid yes and no questions. Include a question about what effect the event had on the person.
4. Conduct the interview. Record the full name of the person, the date and place of the interview, and your name. As you ask questions, record them with a tape recorder or video camera, or take notes. Encourage the person to fill in interesting details of the story and to describe how he or she felt.
5. Finally, write what was said in the interview, leaving in the most important or most interesting things the person said. Include as many direct quotes as you can.

CHAPTER 2 REVIEW

1. What kinds of information can we learn from fossils?
2. Describe continental drift. What effect does tectonic force have on landmasses?
3. Name four ways that mountains are formed.
4. The Ring of Fire includes what kinds of mountains?
5. What are lahars?
6. Name at least three ways the land was changed by the eruption of Mt. St. Helens.
7. Which mountain do scientists label as our most dangerous volcano?
8. Describe how lava helped form the Columbia Plateau.
9. What makes up the soil of the Palouse Hills region and how was it deposited?
10. Describe the process that produced the Bretz Floods.
11. How did the Bretz Floods change the Columbia Plateau?
12. What is Washington's most famous Ice Age animal?